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(NASA-CR-161084) DEVELOP REAL-TIME
DOSIMETRY CONCEPTS AND INSTRUMENTATION FOR
LONG TERM MISSIONS Technical Progress
Report, Feb. 1980 - Feb. 1981 (Pacific
Northwest Lab.) 13 p HC A02/MF A01 CSCL 14B G3/35

N81-32471

Unclassified
27460

Develop Real-Time Dosimetry Concepts and Instrumentation for Long Term Missions

Technical Progress
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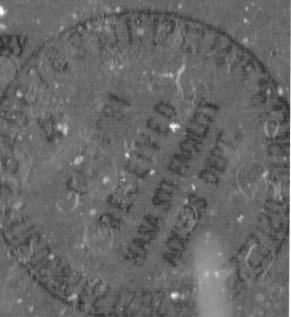
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April 1981

Prepared for National Aeronautics and Space
Administration Lyndon B. Johnson Space Center
Order No. T-794H under a Related Services
Agreement with the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
by Battelle Memorial Institute

 Battelle



INTRODUCTION

The goal of this project is to develop a rugged portable dosimetry system, based on microdosimetry techniques, which will measure dose and evaluate dose equivalent in a mixed radiation field. Development of the desired dosimetry system can be divided into three distinct areas: development of 1) radiation detector, 2) electronic system, and 3) mathematical techniques. Work has proceeded satisfactorily in all three of these areas during the first year of this effort.

DETECTOR DEVELOPMENT

Two spherical tissue equivalent proportional counters simulating tissue volumes approximately two micrometers in diameter will be used in the planned dosimetry system. Detectors built using conventional techniques would be unsatisfactory since the tissue equivalent plastic gradually evolves vapors which cause a marked reduction in detector gain and resolution. In addition, use in the space shuttle adds requirements of vibration resistance and independence from gravitational acceleration which are not normally considered in detector design. Recently, W. Quam at EG&G Santa Barbara Division has developed techniques for processing the plastic and assembling detectors to minimize absorbed gas. EG&G has agreed to build prototype detectors for this project under their Department of Energy contract and a memorandum purchase agreement. The first detector, intended primarily to test the effectiveness of their new construction techniques in reducing detector gas contamination, has a nominal inside diameter of 5.7 cm with .25 cm walls and is designed with support at both ends so that it will resist vibration and acceleration loads. Its magnetically actuated calibration source is spring loaded so that it will operate under weightless conditions, and electrical and gas connections are designed to minimize signal noise and detector mass. This detector has been under test since September.

The detector breakdown voltage is lower than expected, approximately 650 volts. This may be due to irregularities in the anode wire, and it may be possible to obtain higher breakdown voltages in future detectors. At 600 volts the gas gain with a tissue equivalent CO_2 methane mixture is approximately 34; with pure propane the gain is approximately 180. A gas gain between 150 and 200 is appropriate for a detector intended to record events between 1 and 200 keV/ μm .

To provide computer control of the calibration source, a relay coil was adapted with suitable pole pieces and fitted to the detector housing. In order to reduce stray capacitance and therefore preamplifier noise, a low noise charge sensitive preamplifier was fitted into the mounting base of the detector, (Fig. 1) resulting in an overall system noise of 180 electrons rms with voltage applied to the detector. Since the minimum measurable ionization is generally assumed to be about 50 times the electronic noise divided by the gas gain this system should be effective down to about 1.6 keV or LET of 0.8 keV/ μm .

The gas gain is remarkably stable (Fig. 2) having decreased about 5% in the first 10 days, and another 5% in the next 100 days. There appears to be a slight temperature dependence in the system, and the gain appears to increase a few percent in the first hour of operation after being turned off for a few hours. All of these gain shifts are well within the range of automated correction by adjusting the anode voltage.

ELECTRONIC SYSTEM

A complete multichannel analyzer system has been assembled and partially tested (Fig. 3). Three analog input channels are incorporated, two of them using a common detector with different values of gain between the detector and ADC boards (Fig. 4). The ADC boards are designed to minimize power consumption. Each board contains an upper level discriminator (reject), a lower level discriminator (permissive), and a peak detector which tells the sample/hold (S/H) circuit to save the

value of the incoming pulse. The S/H output is fed to an ADC integrated circuit for digitizing when strobed by the peak detector. A double buffer flag system saves the fact (and data) that a second ADC has made a conversion while data from a "first" one is being stored. The ADC is very linear, as illustrated for the first 40 channels in Fig. 5. The relative standard deviation of the channel width is 12%. There is a two channel offset at zero which will not result in loss of data since it will be below the lower level discriminator. In order to prevent errors on the values of the energy imparted, the zero offset will be considered in the calculations.

After conversion, a seven bit word representing the pulse height is stored in the multi channel analyzer (MCA) memory, which is 1K x 12 bits. Double precision storage is utilized, giving a count capacity of 16.7×10^6 counts per channel. Storage uses the conventional "add 1" method, whereby the contents of the memory at the location specified by the data word (combined with the detector ID) are dumped into a scaler, the scaler incremented by one, and the scaler contents restored at the same location. If the scaler overflows when it is incremented, the resulting zero contents are stored at the present location and the high order word corresponding to that location is then incremented and restored, thus implementing the double precision store. Provisions are made so that the microcomputer (μ C) can turn off the MCA action, address the memory channel by channel, and read the contents into the μ C's memory for processing. The μ C can also clear the scaler (above) and reload the MCA memory with zeroes, thereby clearing it for the next accumulation.

Until a count comes in, the whole system is quiescent. When a flag is set signifying that an A/D conversion has been completed, the store process is set into motion and is sequenced by a controller.

High voltage outputs for the detectors are under control of the μ C via a register and D/A converter which controls the reference input to the supplies. A spectrum will be taken using the internal calibration source, the center of the calibration peak found by the μ C, and the high voltage adjusted by the μ C, register, and DAC until the peak

falls in the correct channel. During the development process a commercial microcomputer will be used to substitute for the microprocessor which will also be used to calculate the dose and radiation quality.

The original system plan incorporated commercially available linear amplifiers. However, in order to conserve power, other amplifier designs are being considered. Two commercial amplifiers being used in testing the detector consume 4.5 watts. A specially designed amplifier with two output gains consumes about 1.1 watts.

EVALUATION OF RADIATION QUALITY

Algorithms for processing the energy deposition data are being developed first for use in a commercial microcomputer. This machine has capacity similar to that of any microprocessor system which could reasonably be used in the instrument being developed. Use of the microcomputer allows easy implementation of a variety of different programs to test their performance under different conditions of energy deposition and statistical noise. The number of counts per channel in the measured spectrum is a Poisson random variable determined by the shape of the distribution, the detector diameter, and the dose. At low doses the number of large events is small and quite variable, so any estimate of the quality will be uncertain. The minimum dose at which a given algorithm produces values of quality within a specified standard deviation, as well as the accuracy of that estimate of quality, will depend on the algorithm. Thus minimum dose (and time at a specified dose rate) needed to obtain an estimate of the radiation quality may be as important a consideration in choosing between algorithms as is accuracy. In order to test various algorithms a typical microdosimetry spectrum for a mixed neutron and gamma ray radiation is entered in an idealized form (no statistical noise) and the test program then generates a spectrum for a specified dose with appropriate noise. The algorithm being tested is then used to calculate the dose and dose equivalent.

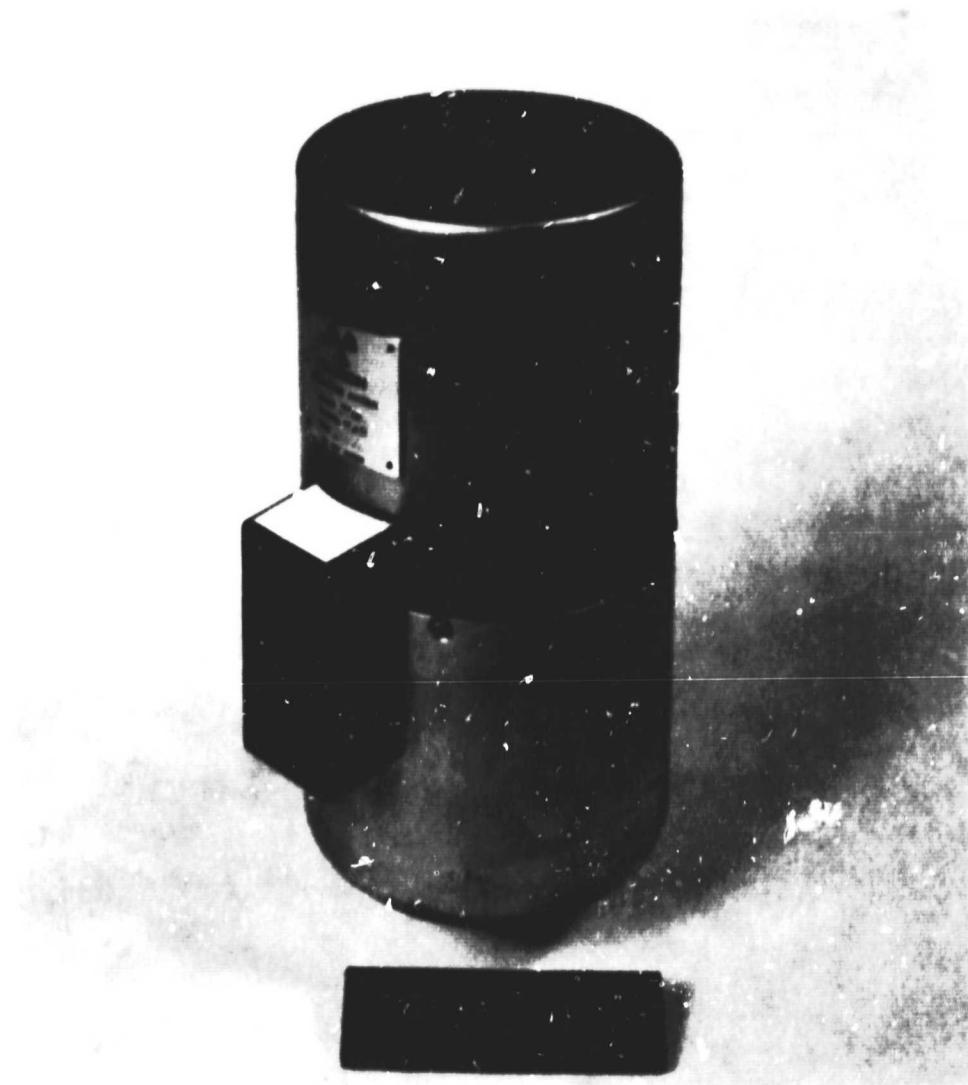
The spectrum being used for preliminary tests covers from .1 to 12.8 keV/ μ m. In those channels where the mean number of events will exceed twenty, a normal random number generator is used. For channels where the number of events is expected to be less than twenty, a Poisson random number generator is substituted. Three basic types of algorithm have been tested. These are: $q = .8 + .14 \bar{y}_D$, the new definition proposed by H. H. Rossi, and unfolding the dose distribution in LET and applying the ICRU definition. The first method produces an artificially low estimate of q for the test spectrum which contains a significant fraction of x-ray events. The proposed new definition,

$$q = \int y^{*1.5} d(y)dy, \quad (1)$$

produces relatively large values for the quality, but the mean of 20 samples is essentially constant (within 2%) from 10^{-2} down to 10^{-4} rad, then drops 20% at 10^{-5} rads. This drop in the mean value of the calculated quality at low dose is characteristic of all three algorithms tested; and may be the result of a bias in the Poisson random number generator. The relative standard deviation of the quality estimated by formula 1 is about 50% at a dose of 10^{-5} rad for the test spectrum from .1 to 12.8 keV/ μ m. This variation is expected to be even larger for a distribution extending to 256 keV/ μ m. The relative standard deviation decreases exponentially to 1.6% at 10^{-2} rads. The estimates of quality based on unfolding the LET distribution from the measured distribution approximately parallel those derived from equation 1 but the magnitude of the quality is lower, in line with the current ICRU definition. These algorithms will be extended to include the simulated data obtained at two amplifier gains so that energy depositions to 256 keV/ μ m will be included.

Milestones for Third 6 Month Period

- May 15 Complete hybrid TTL - CMOS prototype with single detector.
- June 15 Make preliminary choice of radiation quality algorithm.
- July 1 Choose and order microprocessor.



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Figure 1. Tissue equivalent proportional counter package including preamp housing (lower portion) and solenoid (in rectangular box) to activate calibration source.

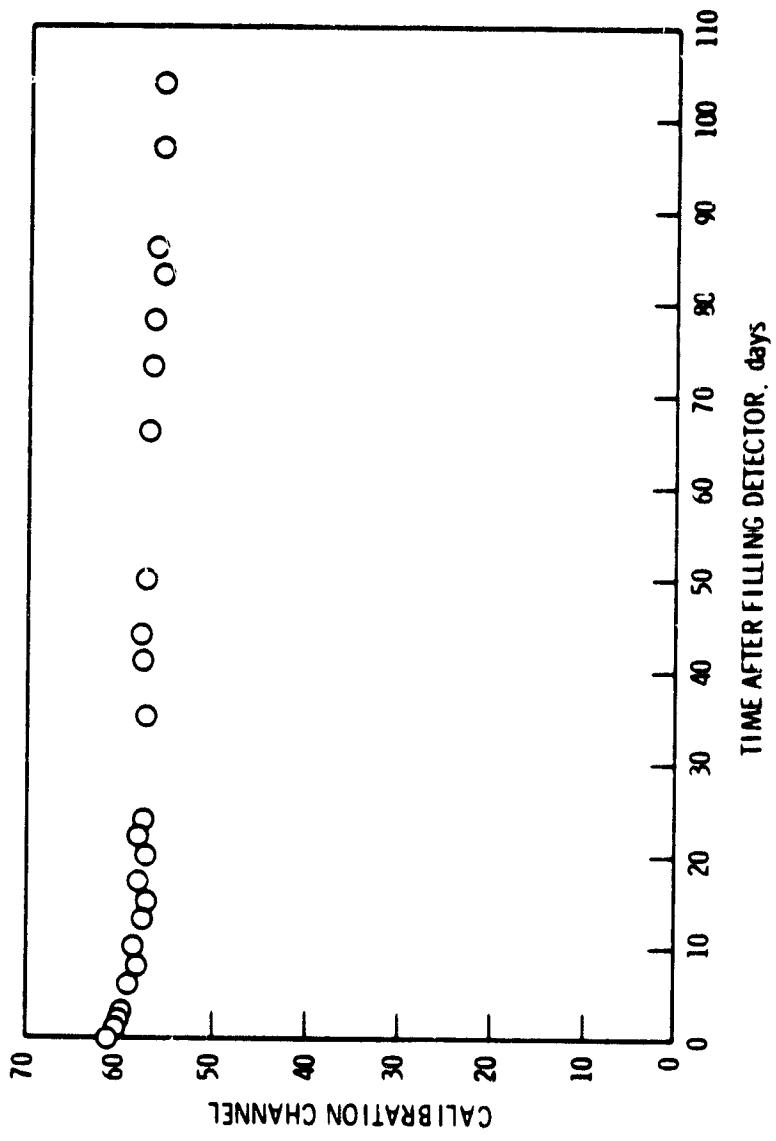


Figure 2. Proportional counter gain (position of 244 cm^{-1} calibration peak) for 100 days after filling with propane.

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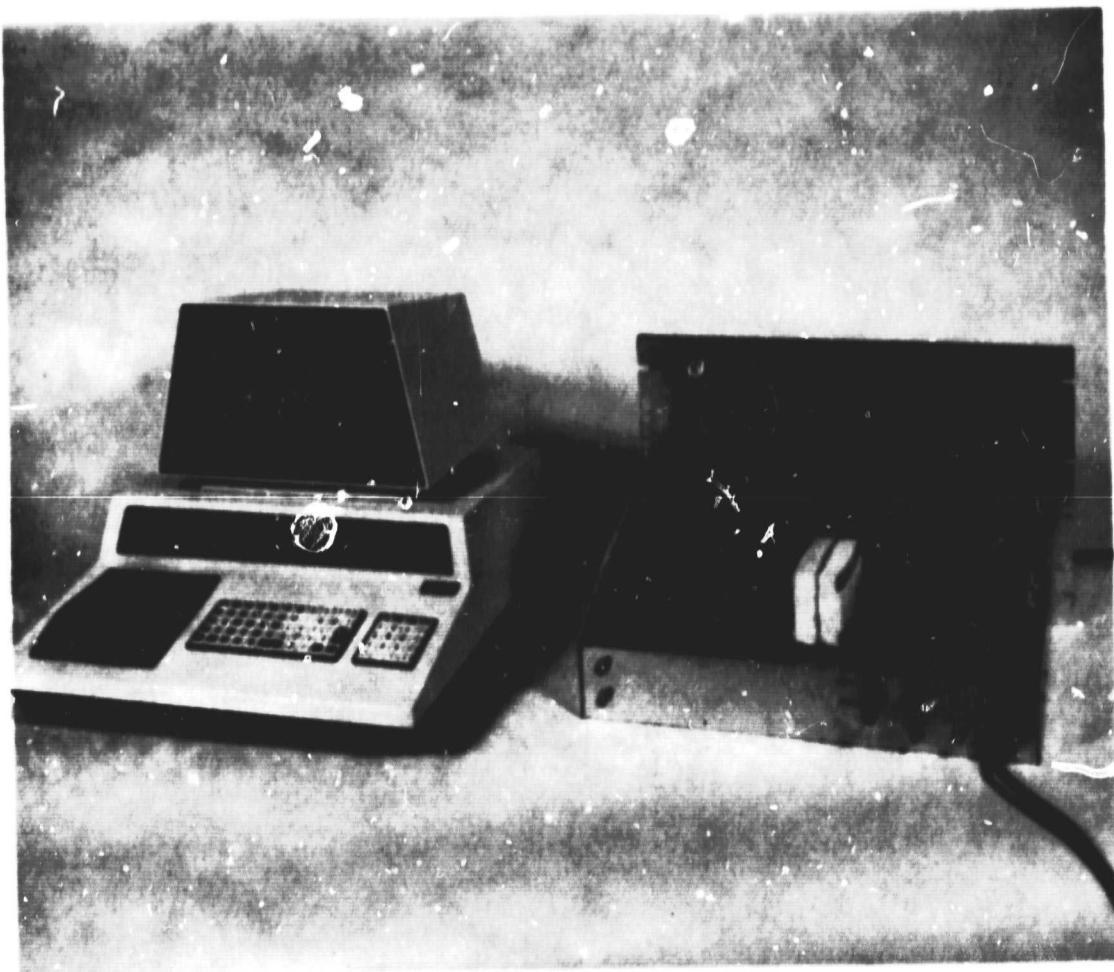


Figure 3. Hybrid CMOS - TTL prototype analyzer and microcomputer.

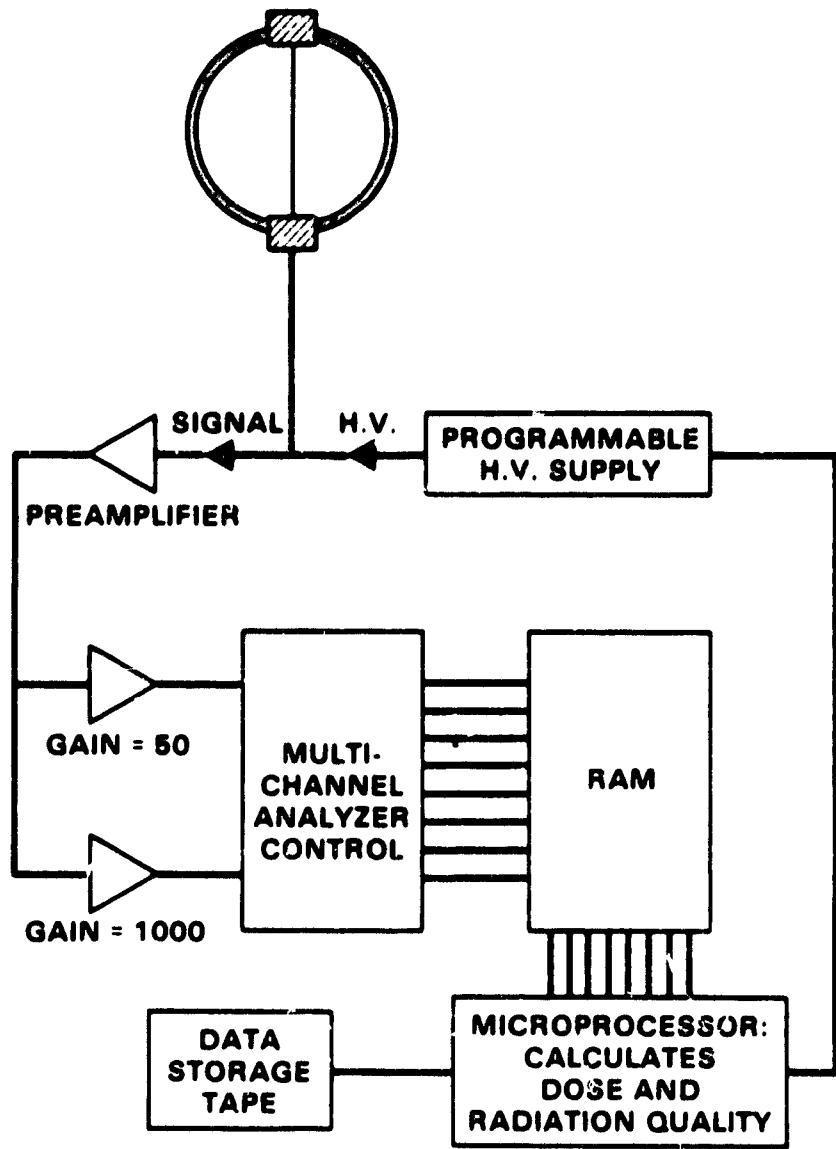


Figure 4. Block diagram of electronic system for one detector with two amplifier gains.

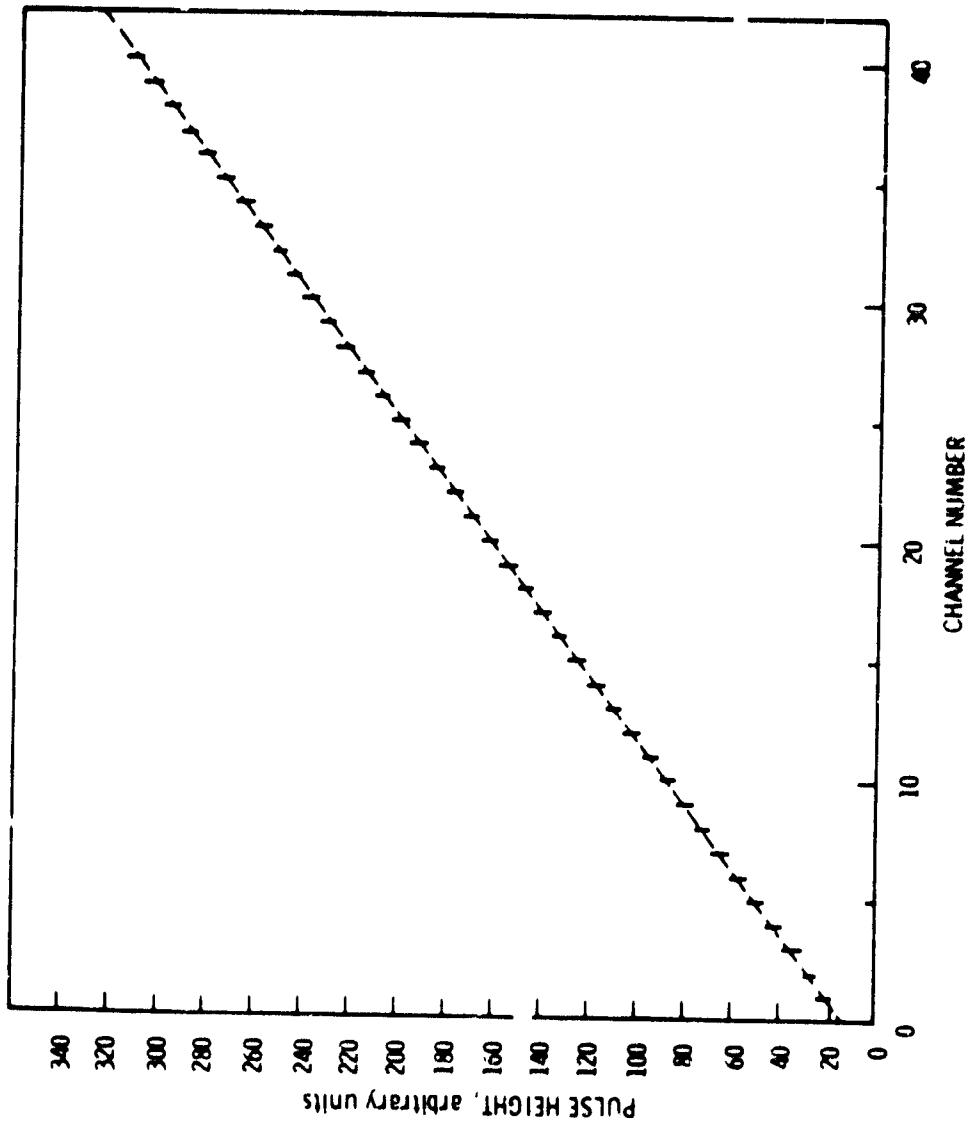


Figure 5. Range of pulse heights falling in each channel defined by analog to digital converter.